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UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
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INFORMATION CIRCULAR

MINING AND MILLING METHODS AND COSTS AT THE TENNESSEE-SCHUYLKILL CORPORATION MINE, CHLORIDE, ARIZ.

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BY

JACOB SCHODER AND PAUL T. ALLSMAN

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MINING AND MILLING METHODS AND COSTS AT THE TENNESSEE-SCHUYLKILL CORPORATION MINE, CHLORIDE, ARIZ.[1]

By Jacob Schoder[2] and Paul T. Allsman[3]

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[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7077."

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INTRODUCTION

This is one of a series of papers published by the Bureau of Mines on mining and milling methods and costs.

The Tennessee-Schuylkill Corporation, Chloride, Ariz., mines and mills a lead-zinc ore containing gold, silver, and a small amount of copper. The mill products are lead and zinc concentrates that are shipped to smelters. The company was the second largest producer of lead and zinc in Arizona in 1937 and was seventh in gold production.

Operations discussed are those being conducted at the mine in October 193 and are representative of the complete operating period from 1936 to date.

ACKNOWLEDGMENTS

The authors wish to thank R. L. D'Arcy, mine superintendent, B. M. Lee, mill superintendent, F. B. Eichelberger, assistant secretary and treasurer, and S. K. Garrett, geologist and engineer, for their assistance in accumulati data for this paper. Production statistics were compiled by C. N. Gerry of the Mineral Production and Economics Division, Bureau of Mines, Salt Lake Cit Utah (T. H. Miller, supervising engineer).

SITUATION AND CLIMATE

The mines and mill of Tennessee-Schuylkill Corporation are at the wester foot of the Cerbat Mountains about 1 mile east of Chloride in the Wallapai mining district, Mohave County, Ariz. The Cerbat Mountains form a typical desert range that extends about 30 miles north from Kingman, a town about 60 miles southeast of Boulder Dam. Peaks attain altitudes of 5,000 to 7,000 fee and rise sharply for 1,500 to 3,500 feet above detritus-filled desert valleys

Chloride may be reached over paved highway U.S. 93, 21 miles north from Kingman, Ariz., or 60 miles south from Boulder Dam.

The climate is typical of the arid, semimountainous, desert region of the Southwest. Seasons are open, and rainfall is scant.

HISTORY AND PRODUCTION

Most of the mines of the Cerbat Mountains were discovered between about 1863 and 1905. Gold, silver, and lead were the only metals sought. Rich silver chloride, lead sulphide, and native gold ores were exploited at first. With cheaper transportation, smelting facilities, and improved milling methods lead-zinc ores became more important.

The Tennessee mine is said to have been discovered in 1894 by A. M. McDuffee and operated intermittently up to 1912. From 1913 to 1917 the mine was operated by the Needles Mining & Smelting Co., a subsidiary of the United States Smelting, Refining & Mining Co. A smelter was erected at Needles, Calif., to treat a jig-mill concentrate. During this period the mine made its greatest production. The largest annual production was in 1937.

After a period of inactivity the Monarch Lead Co. in 1928 combined the Tennessee and adjoining Schuylkill mines under one management. A 150-ton flotation mill designed to produce a lead and a zinc concentrate was erected but was never operated by that company.

In 1936 the Tennessee-Schuylkill Corporation was formed. The mine was unwatered, cleaned out, and made ready for production. This company has operated continuously at near capacity from 1936 to date (November 1938).

The property now includes about 131 acres, of which about 86 acres are patented lode claims, 5 acres comprise a patented millsite, and the reminder is unpatented land.

Table 1 gives the production of the Tennessee and Schuylkill mines from 1901 to 1938.

TABLE 1. - Gold, silver, copper, lead, and zinc recovered from ores at the Tennessee-Schuylkill mine, Chloride, Ariz., from 1901 to 1938[1]

Year	Ore, tons	Concen-trate, tons	Gold, ounces	Silver, ounces	Copper, pounds	Lead, pounds	Zinc, pounds
1901..	25,805	-	8.87	2,469	-	4,421,678	-
1902..	7,567	-	85.89	29,448	-	1,619,640	-
1903..	1,090	-	15.26	4,360	-	279,468	-
1907..	154	-	23.89	2,047	235	90,960	-
1910..	70	10	3.22	127	-	6,654	-
1911..	998	328	78.63	2,638	1,837	97,572	87,486
1912..	1,358	988	266.67	13,127	2,361	459,771	260,966
1913..	29,486	14,360	1,370.29	106,924	16,568	4,740,278	4,233,642
1914..	22,081	12,671	739.15	74,748	11,981	3,657,302	4,932,108
1915..	47,633	22,187	2,191.00	171,366	45,000	6,034,998	8,351,839
1916..	47,013	19,777	1,564.00	135,158	32,285	5,086,177	7,517,627
1917..	41,133	21,347	1,914.00	160,981	55,300	5,039,156	8,352,860
1926..	164	71	12.71	819	435	32,024	32,697
1929..	58	29	4.41	307	183	15,142	13,008
1936..	12,233	3,239	2,870.00	40,850	24,300	1,433,000	1,000,000
1937..	59,990	12,084	10,467.00	138,960	100,000	4,553,000	3,414,000
1938..	54,092	11,340	9,642.56	107,720	86,500	3,792,450	5,449,656
Total.	350,925	118,431	31,257.55	992,049	376,985	41,359,270	43,645,889

[1] Compiled by C. N. Gerry, Division of Mineral Production and Economics, Bureau of Mines, Salt Lake City, Utah.

GEOLOGY

The geology of the Cerbat Mounatins has been discussed recently by Hernon[4] and that of the Tennessee-Schuylkill by Garrett.[5] Other[6] earlier writers have contributed to the geologic discussion of the region.

The Cerbat Range is made up of pre-Cambrian crystalline rocks, later crystalline rocks of unknown age, and volcanic rocks probably of Tertiary and Quaternary age. The crystalline rocks form a complex predominantly of granite with diorite and gabbro, all generally gneissic and intruded by pegmatite, granit diabase, granite porphyry, and lamprophyric dikes. Small blocks of amphibolite occur locally.

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[4] Hernon, Robert M., Cerbat Mountains; Some Arizona Ore Deposits: Arizona Bureau of Mines Bull. 145, 1938, pp. 110-117.

[5] Garrett, S. K., Tennessee-Schuylkill Mine; Arizona Ore Deposits: Arizona Bureau of Mines Bull. 145, 1938, pp. 117-119.

[6] Schrader, F. C., Mineral Deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz.: Geol. Survey Bull. 397, 1909, pp. 27-42.
Bastin, E. S., Origin of Certain Rich Silver Ores Near Chloride and Kingman, Ariz.: Geol. Survey Bull. 750, 1924, pp. 17-39.

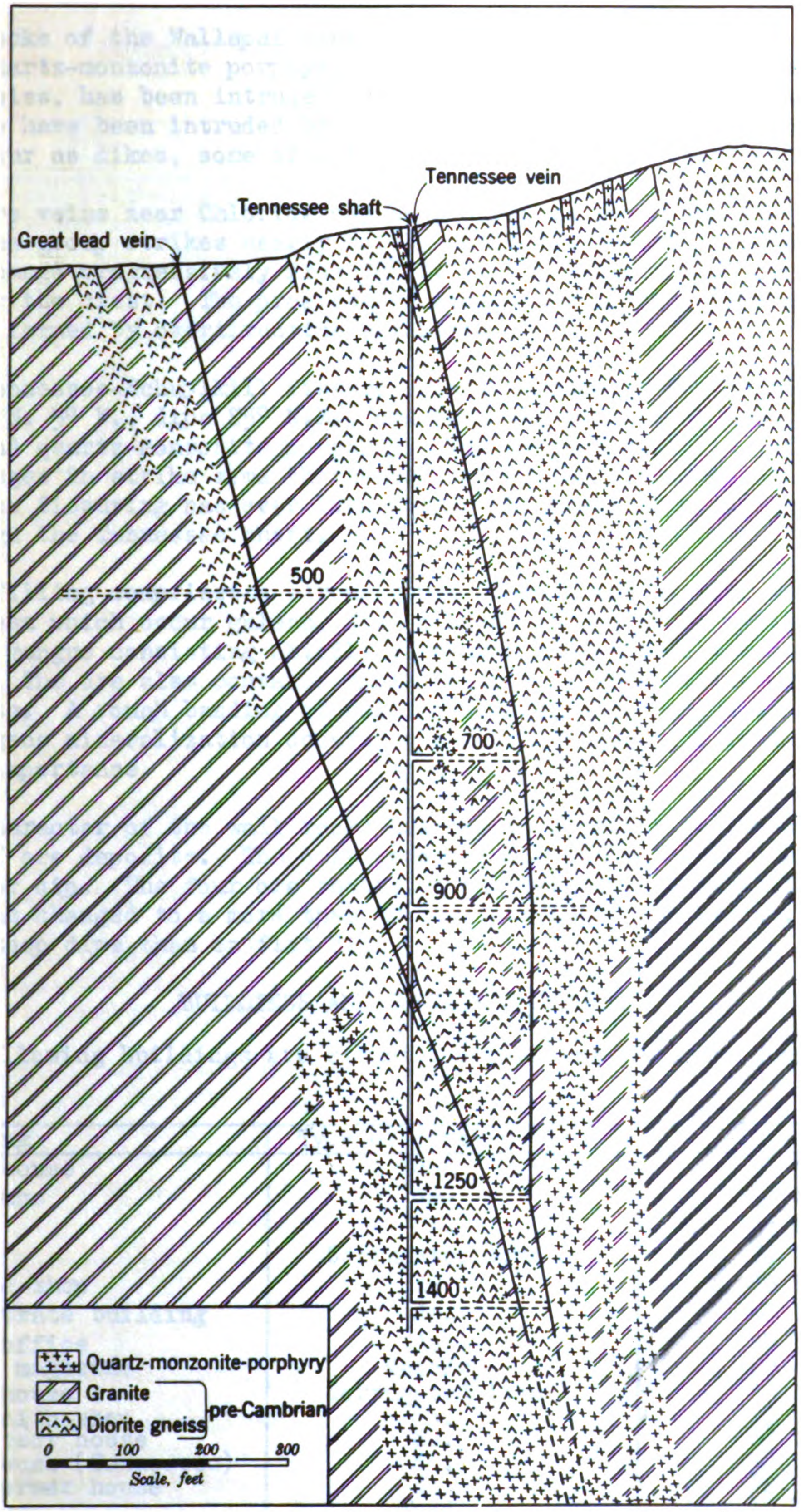

Figure 1.—Geologic cross section through Tennessee shaft, Tennessee-Schuylkill mine, Chloride, Ariz. (after Garrett).

The rocks of the Wallapai mining district may be grouped as diorite gneiss, granite, quartz-monzonite porphyry, rhyolite, and diabase. The oldest rock, diorite gneiss, has been intruded by granite, and both the diorite gneiss and the granite have been intruded by quartz-monzonite porphyry. The rhyolite and diabase occur as dikes, some of which occupy the same fissures with the veins.

Fissure veins near Chloride may be grouped in two classes according to strike. One group strikes nearly north, while the second strikes N. 25° W.; the dips change progressively from 35° E. at the western foot of the range to 85° W. near the crest. The progressive steepening of dips suggests that fissures were formed by overthrusting stresses.

The Tennessee-Schuylkill fissure vein is traceable for nearly 2 miles; it strikes N. 5° W., dips 85° N.E., and cuts the complex of diorite gneiss, granite, and quartz-monzonite porphyry. The average width is 5 feet. At abrupt changes in strike some "horsetailing" of the fissue has taken place but no cross fissuring has ever been found. Figure 1 is a geologic cross section through the Tennessee shaft.

Vein filling comprises a strong gouge on both the hanging wall and foot wall, between which occur galena, fine-grained gold-bearing pyrite, and sphalerite in a gangue consisting chiefly of quartz and soft, altered fragments of wall rock. The ore also contains small amounts of crystalline pyrite and arsenopyrite. A rough banding of sulfide minerals and gangue is often apparent. Some supergene mineralization occurs to a depth of about 80 feet, but it is of little importance.

The character of the wall rocks has had no apparent influence on extent or grade of ore deposits. The only recognizable influence is due to a change in strike or dip. The four ore shoots of the Tennessee-Schuylkill occur where the vein has changed to a more than average northwesterly strike. Shoots are wider on steep dips than on flat dips.

BUILDINGS AND SURFACE EQUIPMENT

The following buildings are situated convenient for operations on the surface:

Building	Type of construction	Size, feet
Staff house	Wood	65 by 30
Residence	do.	30 by 20
Do.	do.	65 by 20
Mill	Corrugated iron	70 by 50
Machine shop	do.	56 by 20
Concentrate building	do.	40 by 25
Assay office	do.	30 by 17
Powder magazine	Masonry	20 by 15
Changehouse	Corrugated iron	35 by 35
Blacksmith shop	do.	30 by 20
Compressor house	do.	67 by 37
Hoisthouse (Tennessee)	do.	30 by 28
Transformer house	do.	28 by 25
Oilhouse	Wood	10 by 10
Warehouse	Corrugated iron	25 by 15
Office	Wood	35 by 20
Hoisthouse (Schuylkill)	Corrugated iron	80 by 25

The following tanks are used for the purpose designated:

Number	Type of construction	Diameter by height, feet	Use
1	Galvanized iron	10 by 6	Mill-water storage.
2	do.	10 by 8	Domestic water.
2	do.	10 by 4-1/2	Fuel oil.
1	do.	6 by 3	Stove oil.
1	Wood stave	20 by 10	Tailing thickener.
1	do.	13 by 10	Mill-water storage.
1	do.	18 by 12	Do.
1	do.	14 by 10	Do.
2	do.	12 by 10	Do.
1	do.	10 by 8	Do.

The following table gives the major items of equipment installed on the surface:

Place	Equipment
Machine shop	Milling machine, 6-foot lathe, 16-foot lathe, drill press, draw saw, hand breast drill, and 7-1/2-horsepower motor with starter for power.
Timber shed	2-1/2-foot cut-off saw, 12-inch ripsaw, and 10-horsepower motor.
Blacksmith shop	Sullivan steel sharpener and oil furnace.
Hoisthouse (Tennessee)	Ottumwa 2-drum, counterbalanced electric hoist, 100-horsepower slip-ring motor, and switch panel.
Hoisthouse (Schuylkill)	2-cylinder, 1-drum, 5-foot-diameter air hoist.
Compressor house	1,000-cubic-feet-per-minute I.R.-type 10 air compressor, 400-cubic-feet-per-minute Sullivan air compressor (in reserve), 150-horsepower motor, and 75-horsepower motor.
Miscellaneous	40-foot timber head frame with 4-foot-diameter sheave wheel at Schuylkill; 60-foot steel head frame with 2 5-foot-diameter sheaves at Tennessee. 3 150-k.v.-a. transformers, 44,000 to 440 volts. 5 5-k.v.-a. transformers, 440 to 220 and 110 volts. 3-1/2- by 4- by 9-foot bailer.

MINING

Physical Characteristics of Ore and Enclosing Rocks

The wall rocks of diorite gneiss, granite, and quartz-monzonite porphyry generally are hard and stand well in stopes; however, locally the foot- and hanging-wall gouge and occasional fractured slabs tend to slough badly. The

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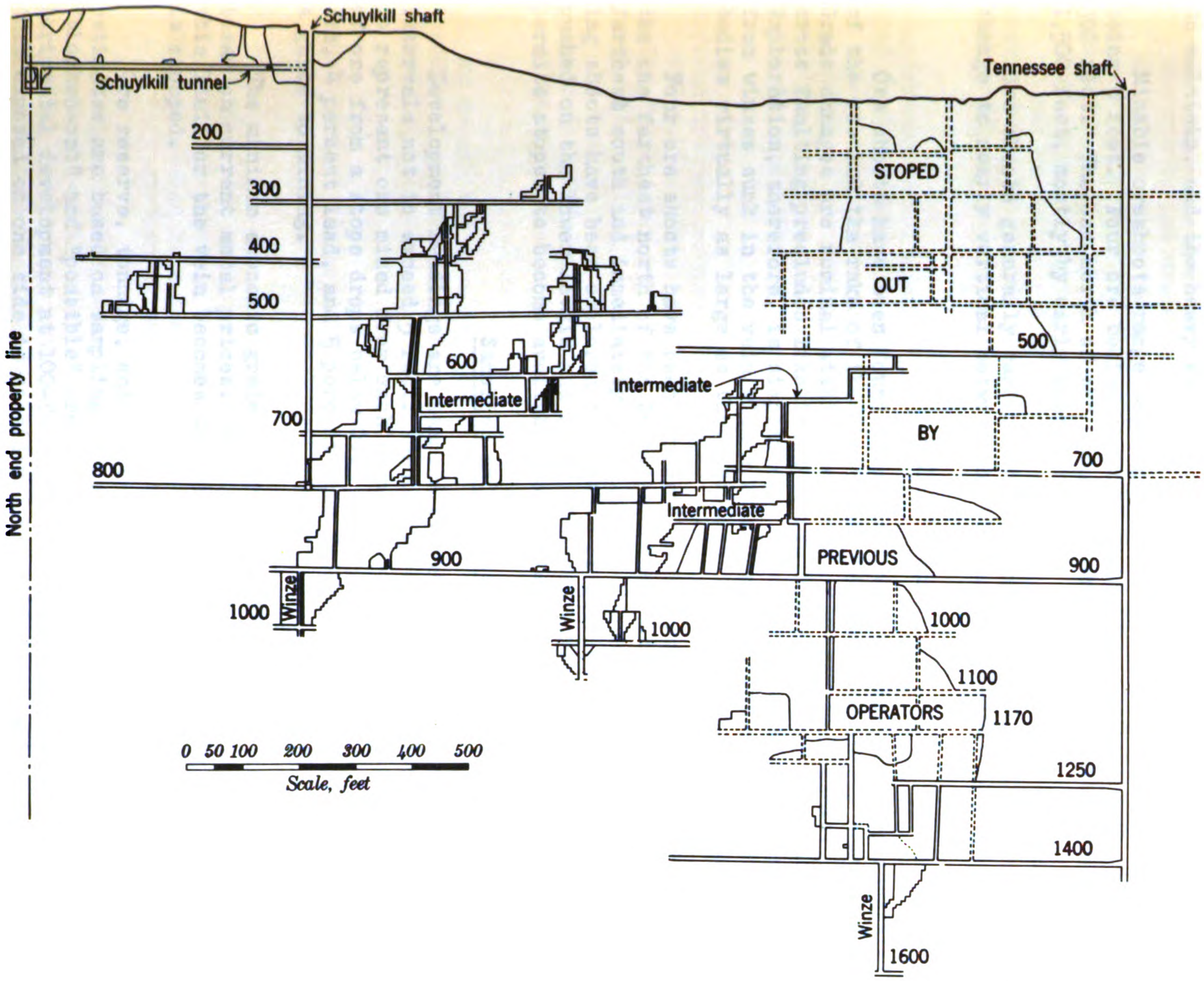

Figure 2.—Longitudinal projection, Tennessee-Schuylkill mine, Chloride, Ariz., showing stoped areas, April 1938, (after Garrett).

vein matter is soft and heavy; relatively little powder is required to break the ore. Except in narrow, barren parts of the vein, drifts are difficult to maintain, and the heavy swelling ground must be relieved occasionally.

Minable oreshoots range between 2 and 14 feet in width, the average being 5 feet. Four ore bodies shown in figure 2 range in length from 35 to 300 feet. The one north of the Tennessee shaft has been mined to a depth of 1,500 feet, mostly by early operators.

Ore shoots generally rake northward above the 900-foot level and tend to change to nearly vertical between the 900- and 1,400-foot levels.

Exploration

Ore shoots have been found to persist with depth. The longitudinal limits of the ore and the rake of the shoots can be predicted fairly accurately. Grade changes are nominal within the range of succeeding levels. Absence of cross faulting precludes likelihood of ore bodies being cut off abruptly. Exploration, therefore, is simplified. Levels are driven from the shafts or from winzes sunk in the vein with a fair degree of certainty of developing ore bodies virtually as large as those exposed on the preceding level.

Four ore shoots have been explored to depths ranging from 150 feet, on the one farthest north of the Schuylkill shaft, to 1,600 feet, on the one farthest south and immediately north of the Tennessee shaft. The two intervening shoots have been explored to a depth of over 1,000 feet. Drifting is being pushed on the lower levels and north of the Schuylkill shaft as fast as mining permits stopes to become available for waste disposal.

Sampling and Ore Estimation

Development headings are sampled by cutting channels across the face at intervals not to exceed 5 feet. Grab samples are taken from cars and combined to represent ore mined from each stope over a 24-hour period. When the grade of ore from a stope drops below 0.15 ounce gold per ton, 2 ounces silver per ton, 4 percent lead, and 5 percent zinc faces are sampled after each round as a guide to mining.

The minimum economic grade of ore mined from stopes is $6.50 per ton, based on current metal prices. When the grade of ore in a stope drops below this limit or the vein becomes too narrow to mine, stoping in that direction is stopped.

Ore reserve, tonnage, and grade estimates are made twice yearly. These estimates are based on sampling of development openings. An estimate of both "blocked-out" and "possible" ore is made. Ore exposed on two sides of horizontal development at 100-foot intervals is designated "blocked out"; that exposed on one side is considered "possible" ore and is extended to a depth of 100 to 150 feet.

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Development

Figure 2 shows a longitudinal projection of development workings. The mine is entered through the Tennessee shaft at the southern end of the ore bodies and the Schuylkill shaft about 1,450 feet north along the strike of the vein. The two mines are connected by the 900-foot level from the Tennessee and a raise to the 800-foot level near the Schuylkill shaft. The 1,600 level is reached from the 1,400 level on the Tennessee side through a winze; the 1,000-foot level is gained from the 900-foot level by two winzes on the Schuylkill side. The 1,250-foot level is being driven around old caved stopes and eventually will open the Schuylkill and intermediate ore shoots for mining above it.

The mining interval generally is 100 feet, and haulage levels generally are established at 200-foot intervals. The 900 is the only haulage level being used at present. Short crosscuts connect the shafts with main drifts; the latter are driven in the vein, except in rare instances where it is found cheaper to run drifts around old caved areas. Occasionally, sublevel drifts have been driven from stopes to remove ore in parts of the vein where it has raked too far away to permit removal by gravity.

The Tennessee shaft is vertical and has two compartments, one for hoisting and one containing a ladderway, piping, wiring, and a counterbalance. The shaft is timbered with 8- by 8-inch timber shaft sets, each compartment being 4 by 4-1/2 feet inside the timber. The Schuylkill shaft is inclined 85° from the horizontal and is the same size as the Tennessee. Both shafts are in the footwall of the vein, the Tennessee extending below the 1,400-foot level and the Schuylkill extending to the 800-foot level. Both shafts were sunk to their present depth by previous operators.

A two-compartment (in part, three-compartment) ore pass and manway is maintained through filled stopes south of the Schuylkill shaft from the 300- to the 900-foot level; it is used for removal of ore from above the 900 level, for bringing in supplies, and for ventilation.

Winzes are sunk in the vein. The rock section is about 12 feet in length and as wide as the vein. They are timbered with 8- by 8-inch timber sets to form two compartments.

Crosscuts are 5 by 7 feet in section. Drifts are driven the width of the vein and 7 feet high; in narrow parts of the vein a minimum width of 5 feet is cut. Drifts are timbered with 8- by 8-inch posts and caps and 4- by 6-inch collar braces. Sets are spaced 4 feet 8 inches, center to center.

In drifting, 12 to 14 holes are drilled per round with mounted jackhammers, using a "V" center cut. Between 50 and 60 sticks of 40-percent gelatin dynamite are used to pull a 4-foot round. Rock is shoveled to 1-ton cars and trammed by hand to a stope being filled or to an ore pass, depending on the grade of the rock.

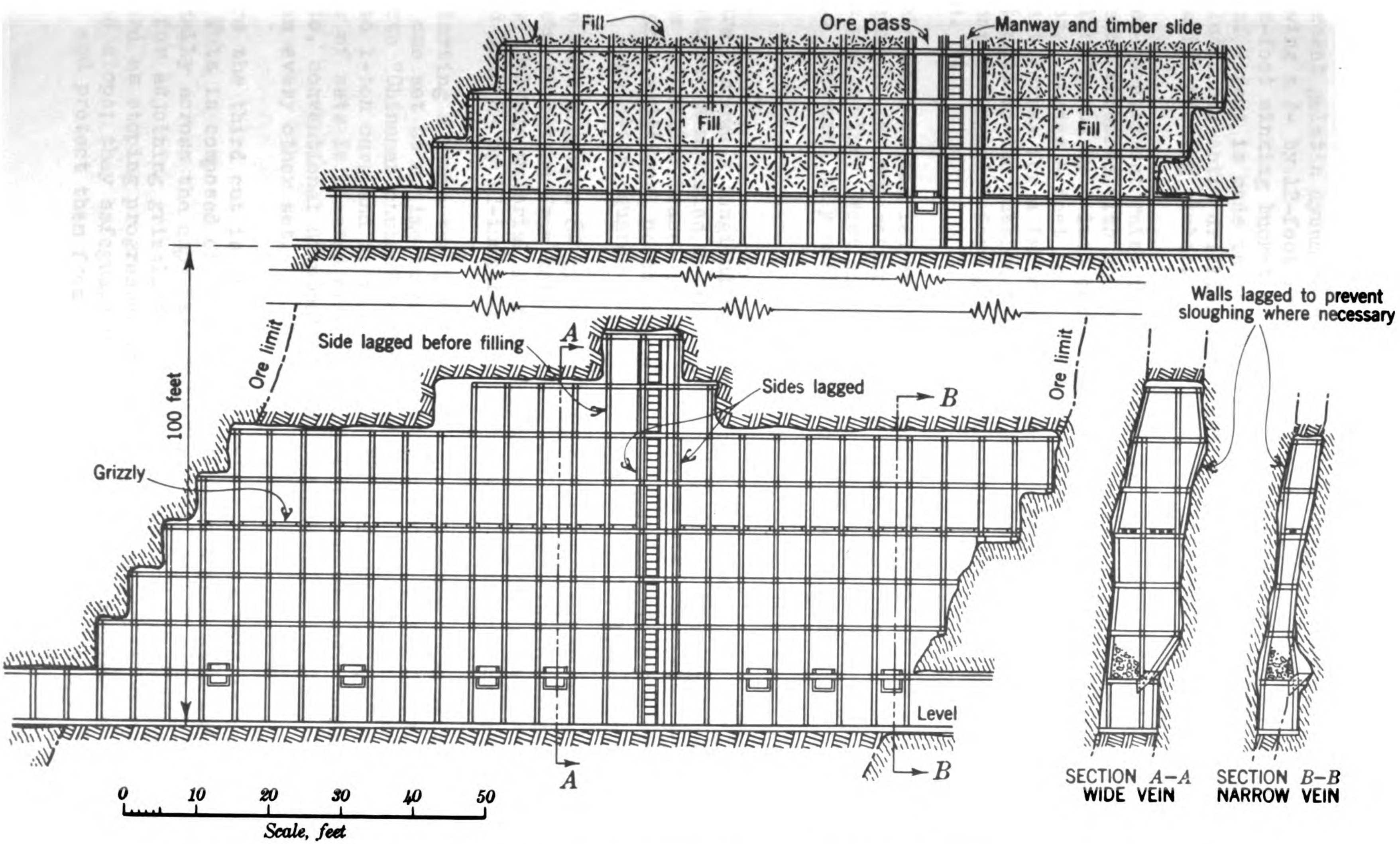

Figure 3.—Longitudinal projection and cross section of square-set method of stoping at Tennessee-Schuylkill mine, Chloride, Ariz.

Winzes are sunk with hand-held jackhammers. About 15 holes and 60 sticks of 40-percent gelatin dynamite are required to break a 4-foot round in a winze having a 7- by 12-foot rock section. The broken rock is shoveled into a 9-cubic-foot sinking bucket and hoisted to a bin on the level above. An advance of 4 feet is made in three shifts by a crew of three men on a shift. This includes one shift drilling and blasting, one shift shoveling and hoisting, and one shift placing timber.

A two-compartment raise is carried up in each stope ahead of mining. The raise is timbered with the regular stope sets, using 6- by 8-inch posts, 8- by 8-inch or 6- by 8-inch caps, and 4- by 6-inch collar braces. Posts are 6 feet long, braces 4 feet long, and caps cut to the width of the stope. One compartment serves for a ladderway and timber and supply slide. This compartment is lagged on the outside for protection. One set adjacent to the manway compartment is lagged before the stope is filled to provide passage for ore and waste.

Development is carried on intermittently as stopes become available for waste disposal. No separation is made of labor, supplies, or cost between development and mining. Most of current development is in ore, and mining cost per ton is increased only nominally by including development.

Stoping

Figure 3 shows a longitudinal projection and transverse sections of a typical stope. A modified square-set method is used. In narrow parts of the vein posts and collar braces follow the changing dip and strike of the walls. In wide parts additional posts and girts are placed along the middle to support the caps. Regulation square-sets are used where the vein is wide enough.

Stope sets comprise 6- by 8-inch posts, 6 feet long, 8- by 8-inch Oregon fir caps cut to extend from wall to wall, and 4- by 6-inch collar braces 4 feet long. Salvage material is used for braces when it is available. The walls are lagged with 2- by 12-inch lagging where it is needed to prevent sloughing.

In starting a stope the first cut is made above the back of the drift by advancing one set at a time in both directions from a stope raise. The ore is blasted onto "Chinaman chutes" built on spreaders between drift posts and is loaded into 1-ton cars and trammed by hand to a transfer raise. The cut for the second row of sets is blasted onto the same Chinaman chutes. Before the third cut is made, conventional dropboard chutes are installed as needed but not closer than every other set.

Before the third cut is broken, a grizzly floor is laid on the second row of caps. This is composed of 6- by 8-inch timbers 6 feet long laid on edge longitudinally across the caps (see fig. 3). The ends of each timber serve as spreaders for adjoining grizzlies. The spacing is 6 inches. Grizzlies are moved upward as stoping progresses and are maintained within 20 feet of the back of the stope; they safeguard workmen, prevent oversize from entering the chutes and protect them from large boulders during blasting.

Ore is completely extracted between levels in a continuous operation. After the next level above is reached, fine ore that has accumulated in the stope is cleaned out thoroughly. These fines are better than the average grade of the ore. Chutes are then removed, except those used in transfer raises, and the floor above the drift is lagged over. Waste from development is dumped between the rails above the stope until it is filled.

Raises are advanced ahead of mining, stopers being used for drilling. Drilling in stopes is done with mounted jackhammers. An average of 6 to 8 holes 4 to 5 feet deep are drilled per set. About 17 sticks of 40-percent gelatin dynamite are required to break a round.

In all drilling, 7/8-inch hexagonal crucible steel and conventional cross bits are used. Starters have a 2-inch gage and finishers a 1-5/8-inch gage. The gage change is 1/8 inch, and the changes in length are about 18 inches. Jackhammer steel is lugged, while stoper steel has plain shanks.

Transportation

Ore is drawn from stopes through conventional drop-board chutes to 1-ton ore cars. That from stopes above the 900-foot level is trammed by hand up to 400 or 500 feet and dropped to the 900-foot level. A short tram is made on the 500-foot level and a 140-foot tram on the 800-foot level to transfer the ore between transfer raises (see fig. 2). Below the 900-foot level all ore is hoisted through a winze to pockets above the level. Hoisting is done by a single-drum hoist gear-connected to a 25-horsepower motor.

A 1-1/2-ton Mancha battery locomotive collects loaded cars on the 900-foot haulage level and trams them 1,000 to 1,400 feet to the station at the Tennessee shaft. Six 17-1/2-cubic-foot cars make up a train. The average grade is 2 percent in favor of the loaded train, and track gage is 18 inches.

Cars are dumped by hand directly into a 1-1/2-ton skip suspended below a service cage. Ore is hoisted 900 feet vertically to a 50-ton coarse-ore bin at the headframe. The rope speed is 800 feet per minute, and a 7/8-inch-diameter hoisting rope is used.

Timber and supplies are brought into the mine on a cage through the Tennessee or Schuylkill shaft, whichever is more convenient. Timber trucks are used to transfer material to working places. Supplies are hoisted into stopes by air hoists through manways equipped with timber slides.

Drainage

About 50 gallons of water per minute is pumped from the mine as part of the mill supply. The main pumping stations are on the 1,400- and 700-foot levels of the Tennessee shaft. Water is pumped from the 1,400-foot-level sump to the 700-foot-level station by a 100-gallon-per-minute duplex horizontal pump driven by a 25-horsepower motor. A duplicate pump is held in reserve.

Water from the Schuylkill side and from the 900-level winze is accumulated in a sump at the 900-foot-level station of the Tennessee. The winze is equipped with a 100-gallon-per-minute Byron Jackson pump powered by a 25-horsepower motor. A 100-gallon-per-minute Ingersol Rand pump powered by a 25-horsepower motor lifts the water from the 900- to the 700-foot level.

All mine water is accumulated on the 700-foot level, where it is pumped to surface by a Worthington triplex pump with a capacity of 100 g.p.m.; it is driven by a 40-horsepower motor. An Ingersol Rand 2-stage centrifugal pump with a capacity of 100 gallons per minute and powered by a 50-horsepower motor is held in reserve for emergency.

Ventilation

All workings above the 900 haulage level are ventilated naturally. The Schuylkill shaft is strongly downcast; air from it passes through the workings and out the Tennessee shaft, which is strongly upcast. A Buffalo fan driven by a 5-horsepower motor forces air from the 900-level station at the Tennessee through a 12- by 12-inch wood pipe down to the 1,250-foot level. The pipe is of wood to resist corrosion from acid waters falling in the shaft. At the 1,250-foot level a booster fan of the same size forces the air through 8-inch-diameter "ventube" to the face of the drift on that level.

The 900-level winze is ventilated by another 5-horsepower Buffalo fan on the 900 level. An 8-inch-diameter ventube conveys the air to the 1,020-foot level of the winze. A small Vano air-driven blower is used to furnish air in emergencies.

Mine Labor

The mine is operated three shifts per day and seven days a week. Limited surface storage necessitates this arrangement. The following table gives occupation, wages, and average number of men required daily to operate the mine:

Occupation	Rate per shift	Number
Miners..........	[1]$5.00	22
Do............	4.50	35
Muckers and trammers.......	4.00	14
Hoistmen........	5.00	8
Mechanics.......	4.00 to 5.50	5
Jigger bosses...	6.00	5
Motormen........	4.50	3
Motormen helpers	4.00	3
		95

[1] Miners receive $0.50 per shift extra for working below the 900 level in winzes and stope.

Mine Power

Power is generated at Boulder Dam at 44,000 volts and distributed by the Citizens Utility Co., Kingman, Ariz. It is stepped down to 440, 220, and 110 volts through transformers at the mine.

The power rate is $0.016 per kw.-hr. metered on the low side of the transformers. The rate is based on the use of 400 kilowatts minimum demand. Generally, about 50 percent of the power is used for mining, including about 10 percent for hoisting.

The only direct current used is on the 900-foot-level station, where a motor-generator set is employed to charge the batteries for the locomotive.

Mining Costs

Table 2 gives the cost of mining at the Tennessee-Schuylkill Corporation for September 1938 and for a period of 9 months in the same year as taken from auditor's report. Table 3 summarizes mining costs for September 1938. Table 4 summarizes costs in units of labor, power, and supplies. These costs are typical of those obtained since mining was begun in 1936.

Dynamite costs $12.75 per 100 pounds, caps $14.75 per 1,000, and fuse $6.55 to $7.75 per 1,000 feet. The average cost of timber is $30 per thousand board feet.

MILLING

The Tennessee-Schuylkill concentrator has a normal capacity of 150 tons per day, although as high as 175 tons have been treated in one day. The process is selective flotation; two products are made, a lead concentrate containing most of the gold and silver and a zinc concentrate with a smaller quantity of the precious metals. The ore is valuable principally for its gold content. A third product, concentrate from a jig preceding flotation, is relatively high in gold. A nominal tonnage of high-grade ore has been shipped direct to a smelter. A small tonnage of custom ore is received.

Figure 4 shows the general flow sheet and figure 5 the details of the selective flotation unit of the mill.

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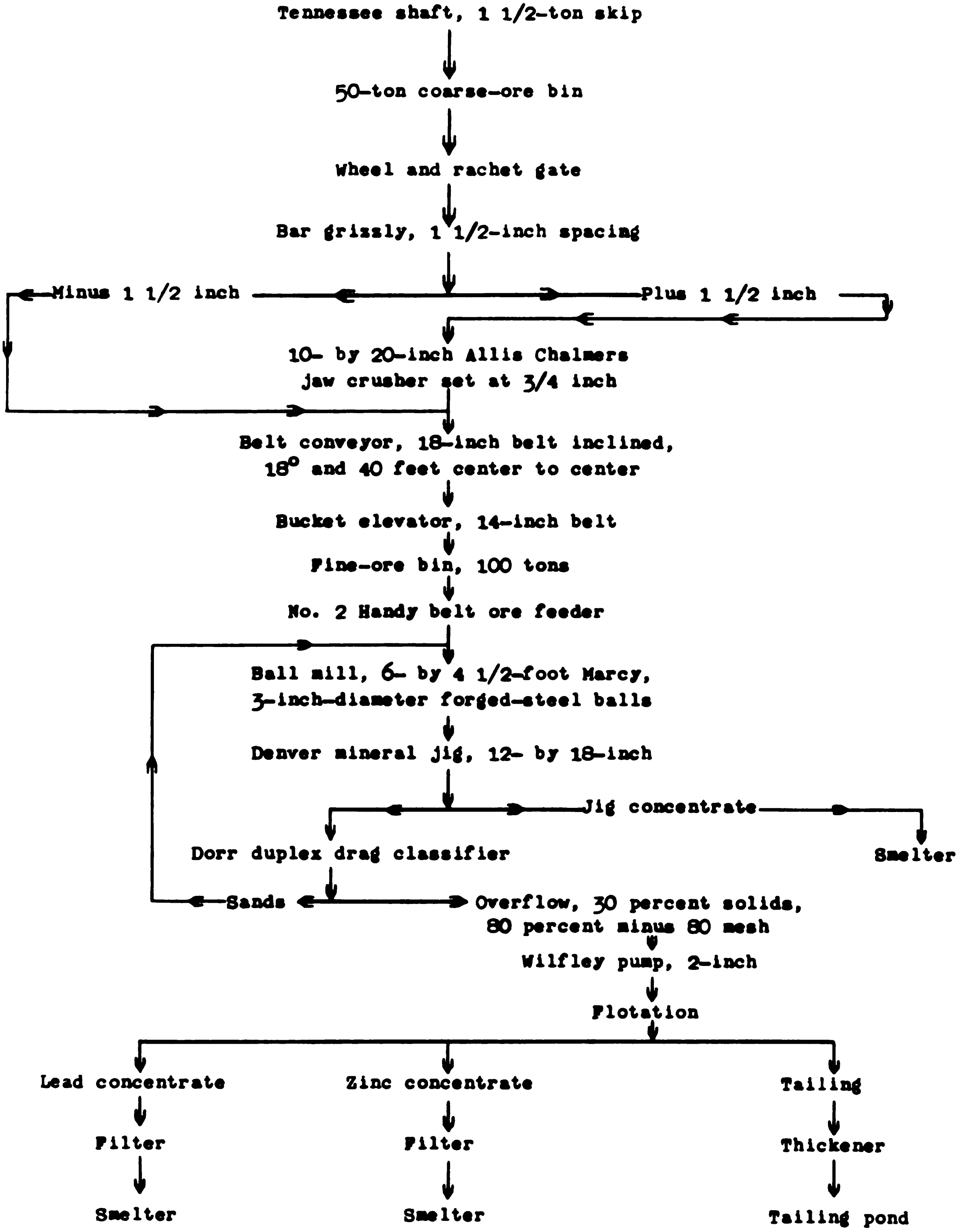
Tennessee shaft, 1 1/2-ton skip
50-ton coarse-ore bin
Wheel and rachet gate
Bar grizzly, 1 1/2-inch spacing
Minus 1 1/2 inch
Plus 1 1/2 inch
10- by 20-inch Allis Chalmers jaw crusher set at 3/4 inch
Belt conveyor, 18-inch belt inclined, 18° and 40 feet center to center
Bucket elevator, 14-inch belt
Fine-ore bin, 100 tons
No. 2 Handy belt ore feeder
Ball mill, 6- by 4 1/2-foot Marcy, 3-inch-diameter forged-steel balls
Denver mineral jig, 12- by 18-inch
Jig concentrate
Smelter
Dorr duplex drag classifier
Sands
Overflow, 30 percent solids, 80 percent minus 80 mesh
Wilfley pump, 2-inch
Flotation
Lead concentrate
Filter
Smelter
Zinc concentrate
Filter
Smelter
Tailing
Thickener
Tailing pond

Figure 4.- Flow sheet of Tennessee-Schuylkill mill, Chloride, Ariz.; capacity 150 tons per day.

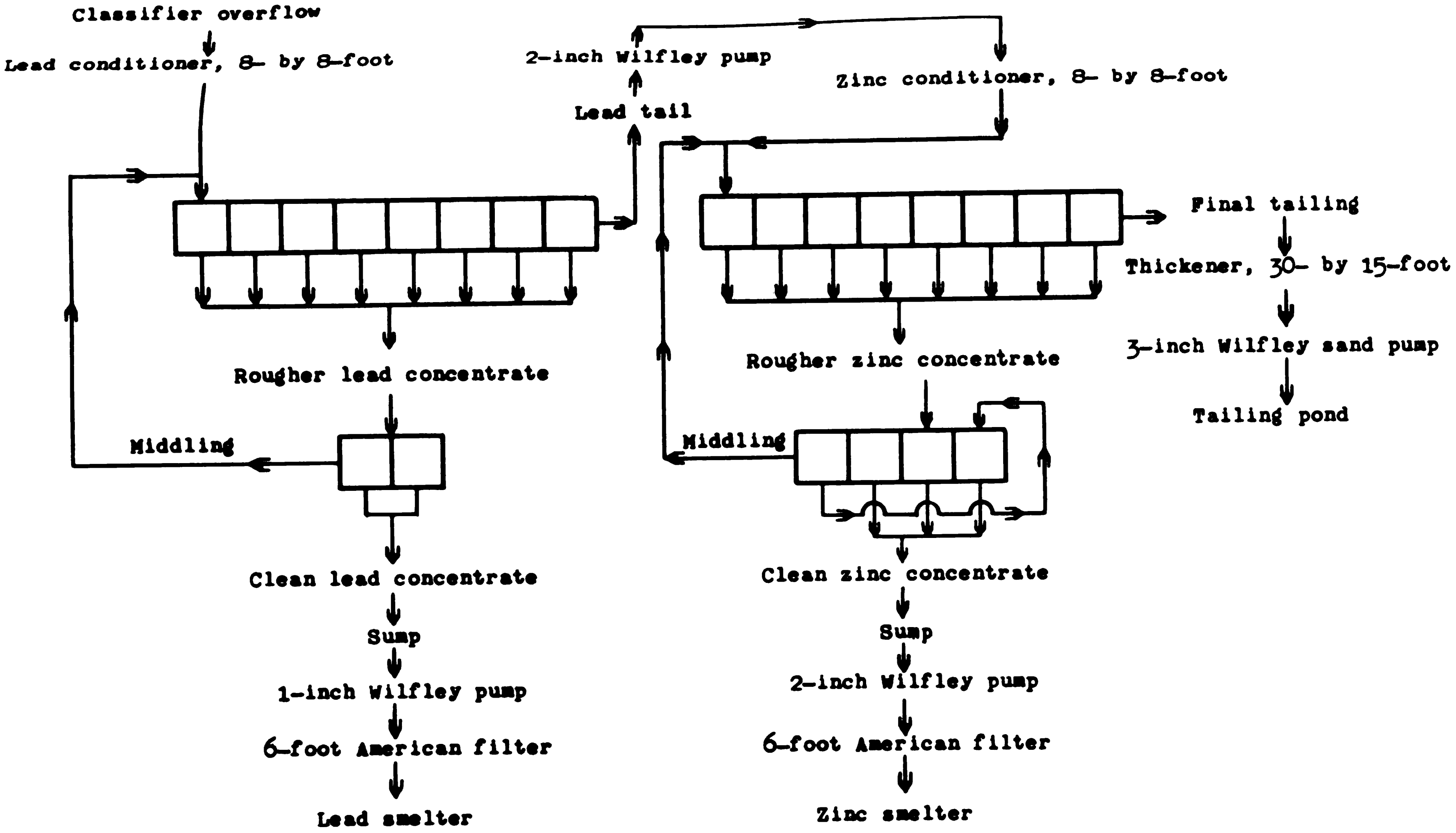

Figure 5.- Flow sheet of selective flotation, Tennessee-Schuylkill mill, Chloride, Ariz.

TABLE 2. - Cost of mining at the Tennessee-Schuylkill Corporation for September 1938 and for the first 9 months of 1938.

Tonnage mined and hoisted........	September, 1938 4,087		9 months, 1938 40,288	
	Amount	Per ton	Amount	Per ton
Salaries and wages:				
Supervision..................	$ 1,134.00	$ 0.2774	$ 11,545.50	$ 0.2866
Stoping and timbering.........	6,717.24	1.6435	72,981.52	1.8115
Tramming and mucking..........	2,226.50	.5448	24,591.65	.6104
Pumping and drainage..........	856.75	.2096	8,238.61	.2045
Hoisting......................	1,191.25	.2915	10,964.52	.2722
Service men...................	590.00	.1443	7,108.45	.1764
Total salaries and wages...	12,715.74	3.1111	135,430.25	3.3616
Drill steel and supplies.....	1,029.97	.2520	6,183.93	.1535
Lumber and timber...............	2,460.29	.6020	25,683.27	.6375
Equipment and repair parts.......	1,450.80	.3550	9,220.89	.2289
Power..........................	1,235.66	.3023	13,502.84	.3352
Explosives......................	560.59	.1372	6,769.70	.1680
Compensation insurance...........	971.81	.2378	10,357.02	.2571
Unemployment tax................	394.47	.0965	4,164.32	.1034
Old-age benefit tax.............	125.88	.0308	1,378.84	.0342
Medical expense..................	4.00	.0010	196.00	.0048
Yard and camp...................	213.23	.0522	2,382.42	.0591
Miscellaneous and office expense 1/	507.86	.1241	5,525.26	.1372
Total mining..............	21,670.30	5.3020	220,794.74	5.4805

1/ One-half of unapportioned expense arbitrarily added.

TABLE 3. - Summary of mining costs, September 1938, Tennessee-Schuylkill Corporation (4,087 tons hoisted)

	Labor	Supervision	Power	Explosives	Timber	Drill steel and supplies	Total
Stoping and development..	$1.64	-	$0.27	$0.14	$0.60	$0.61	$3.26
Transportation...........	.84	-	.03	-	-	-	.87
Pumping and drainage.....	.21	-	-	-	-	-	.21
General underground......	-	$0.28	-	-	-	-	.28
Surface expense..........	.19	1/ .12	-	-	-	-	.31
Taxes and insurance 2/....	.37	-	-	-	-	-	.37
Total..............	3.25	.40	.30	.14	.60	.61	5.30

1/ One-half of assaying, engineering, and office expense.

2/ Includes compensation insurance, unemployment tax, old-age benefit tax, and medical expense.

TABLE 4. - Summary of costs in units of labor, power, and supplies at Tennessee-Schuylkill Corporation for September 1938

Tons of ore mined and hoisted	4,087
A. Labor (man-hours per ton):	
Breaking and timbering	3.35
Mucking and tramming	.82
Haulage and hoisting	.82
Supervision	.29
General	.29
Total labor underground	5.57
Average tons per man-shift	1.44
Labor percent of total cost	57.4
B. Power and supplies:	
Explosives (pounds per ton 40-percent gelatin dynamite)	0.807
Timber (board feet per ton)	20.
Power (kw.-hr. per ton)	19.6
1. Compressed air and mine circuit	17.9
2. Hoisting	1.7
Other supplies in percentage of total supplies and power	36.8
Supplies and power, percentage of total cost	30.4
C. Percentage of total mining cost	87.8

Ore Treated

The ore of the Tennessee and Schuylkill mines is relatively soft for crushing and grinding. The hypogene ore minerals are galena, fine-grained gold-bearing pyrite, and sphalerite. The gangue minerals are several varieti of quartz, crystalline pyrite, and arsenopyrite. A small amount of chalcopyrite is obtained in the concentrates.

The sphalerite occurs as typical "black jack" and "rosin jack." Two varieties of pyrite are found; one occurs as well-crystallized cubes with no gold, and the other is somewhat massive and fine-grained and contains 0.3 to 15 ounces of gold per ton in pure specimens. Gold in the pyrite is extremely finely divided.

Crushing and Grinding

Ore is hoisted from the Tennessee mine in a 1-1/2-ton skip and dumped into a 50-ton-capacity coarse-ore bin. The flow is regulated by a wheel and rachet gate that permits ore to pass over an inclined bar grizzly with 1-1/2-inch spacing between bars. The oversize is broken in a 10- by 20-inch Allis Chalmers jaw-crusher set to discharge a 3/4-inch product. The crusher is driven by a "V" belt from a 20-horsepower motor. The grizzly oversize bypasses the crusher and joins the crushed product. Undersize is about 40 percent of the feed.

Crushed ore is conducted to a 100-ton fine-ore bin by an 18-inch belt conveyor (40 feet long and inclined at 18°) and by a 14-inch bucket elevator.

A No. 2 Handy belt feeder regulated to handle 150 tons in 24 hours discharges the crushed ore to a 6- by 4-1/2-foot Marcy ball mill. The ball mill is charged with 5 tons of 3-inch-diameter forged-steel balls. Manganese-steel liners in the ball mill have a life of about 60,000 tons of ore ground. A circulating load of 1-1/2 times the original feed and a pulp density of about 80 percent solids is maintained. The ball mill is operated at 27 r.p.m. through a herringbone gear and 100-horsepower motor.

Pulp from the ball mill discharges to a 12- by 18-inch Denver Mineral jig, from which about 17 to 20 percent of the gold is recovered in a lead concentrate. The ball mill and jig are in closed circuit with a Dorr duplex drag classifier. The overflow from the classifier is maintained at about 30 percent solids ground to 80 percent minus 80 mesh.

Flotation

The flotation section consists of an eight-cell lead rougher unit followed by a two-cell lead cleaner unit and an eight-cell zinc rougher unit followed by a four-cell zinc cleaner unit. Classifier overflow is pumped to an 8- by 8-foot lead conditioner by a 2-inch Wilfley sand pump. The conditioned pulp goes to the first cell of the eight-cell lead rougher unit. A rougher concentrate is taken from all eight cells and flows by gravity to the first cell of the cleaner unit. A clean lead concentrate is taken from the two cells, and the middling from the last cell goes back to the first rougher cell.

The rougher lead tailing is pumped by a 2-inch Wilfley to an 8- by 8-foot zinc conditioner. It then flows by gravity to the first cell of the zinc rougher unit. A rougher zinc concentrate is taken from the eight cells and cleaned in the four-cell cleaner unit. The cleaner unit produces a clean zinc concentrate and a middling that is returned to the first zinc rougher cell.

Considerable difficulty was experienced at first in attempting to use mine water for flotation. The water was found to be highly acid, often having a pH of 3.5; in addition, it carried considerable amounts of ferric sulfate, ferrous sulfate, zinc sulfate, and calcium sulfate. Attempts to neutralize the water with either soda ash or lime were unsuccessful, as the large quantities of carbon dioxide generated interfered with the flotation of the minerals. An attempt was then made to float the sulfides selectively in an acid circuit, with excellent results. The gold-bearing pyrite was floated successfully with the galena, the zinc sulfide being depressed naturally. Afterward the zinc could be activated and removed from the lead tailing.

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The chief control over flotation consists in properly mixing virtually neutral tailing water, supplemented by other neutral water, with the acid mine water to maintain a pH ranging between 5.4 to 5.8. No other water conditioning is necessary.

Cresylic acid and sodium ethyl xanthate (Z-4) are added ahead of the ball mill, and an additional quantity of the latter is added to the first lead rougher cell. These effect flotation of the galena and gold-bearing pyrite. Copper sulfate, sodium-ethyl xanthate, and cresylic acid are added to the lead tailing in the zinc conditioner to activate and float the zinc sulfide.

The following table gives average consumption of reagents:

	Pounds per ton of ore
Cresylic acid................	0.092
Sodium xanthate (Z-4).........	.175
Copper sulfate...............	1.007

Concentrate Handling

Lead concentrate flows by gravity to a sump, from which it is pumped by a 1-inch Wilfley sand pump to a 4-foot 4-leaf American filter. Zinc concentrate are handled likewise. The filtered concentrates contain about 10 percent moisture.

Lead concentrates and jig concentrates are shipped to the lead smelter of the American Smelting & Refining Co. at El Paso, Tex.; zinc concentrates are shipped to the zinc smelter of the American Smelting & Refining Co. at Amarill Tex.

Concentrates are trucked 22 miles to Kingman, Ariz. The contract price is $1.50 per ton, including loading and unloading. Return supplies are trucke for $2 per ton. The freight rate for lead concentrate from Kingman, Ariz., to El Paso, Tex., for concentrates valued at $40 is $5.50 per ton. The freigh rate on zinc concentrate to Amarillo, Tex., for concentrate valued at $30 is $5.15 per ton. Jig concentrates are shipped separately to El Paso; the avera value per ton is $630 and the freight rate is $10 per ton.

Tailing Disposal and Water Supply

Tailings from the zinc rougher cells are pumped by a 3-inch Wilfley sand pump to the tailing pond. When a shortage of water exists they are first thickened in a 30- by 15-foot thickener. Pulp to the thickener contains 45 to 50 percent solids, and discharged tailings contain 60 to 65 percent solids Water is also reclaimed from the tailing pond by settling. The clear water i pumped back to mill storage by a 5-inch Myer bulldozer pump and a 3-horsepowe motor. The water line comprises a 2-inch-diameter pipe 400 feet long; the head is 35 feet. The set-up provides for reclaiming about 60 percent of the water.

Fresh mill water is pumped from the mine at the rate of about 50 gallons per minute. This is supplemented by water pumped from the Dardanelles mine. A flat rate of $100 per month is paid for this water. A jack-head pump and 3-horsepower motor lift the water an average of 180 feet from the Dardanelles mine to the collar, from whence it flows by gravity a distance of about 1 mile through a 3-inch pipe to the mill storage. About 400 gallons of water per ton of ore is used in the mill, of which 160 gallons per ton of ore is new water.

Sampling and Mill Control

Heads, concentrates, and tails are sampled by hand every half hour. The half-hour samples are combined to represent three 8-hour periods daily.

Tonnage is estimated from the number of skips hoisted and also checked against the cars trammed underground. Concentrates are weighed in the trucks and checked against the estimated tonnage.

Mill Labor

The mill is operated three shifts a day and 7 days a week. An average of 10 men per day are required in the direct operation of the mill; about two service men per day are charged to milling.

The following table gives labor classification at the mill:

Classification	Number per shift	Total per day	Wages per shift
Crushermen.........	1	3	$4.00
Ball-mill operators	1	3	4.50
Flotation operators	1	3	5.00
Tailing attendant..	1 on day	1	4.00
Service men........	2 on day	2	5.00
		12	

Metallurgical Data

Table 5 gives the metallurgical data of the Tennessee-Schuylkill mill for September 1938.

TABLE 5. - Metallurgical data, Tennessee-Schuylkill Corporation, Chloride, Ariz., September 1938

Product	Gold, ounces per ton	Silver, ounces per ton	Lead, percent	Zinc, percent	Iron, percent
Assays:					
Head............	0.185	2.26	3.43	5.15	-
Jig concentrate.	14.98	37.70	36.22	4.77	-
Lead concentrate	.986	13.84	23.22	5.88	25.00
Zinc concentrate	.125	1.87	.59	51.97	-
Tail............	.010	.16	.10	.75	-

TABLE 5. - Metallurgical data, Tennessee-Schuylkill Corporation, Chloride, Ariz., September 1938 (Cont'd)

Product	
General:	
Total tons ore treated	4,278
Days operated	30
Hours operated per day	24
Average tons per 24 hours	143
Total tons concentrate	913.24
Jig concentrate ... tons	8.75
Lead concentrate ... do.	597.18
Zinc concentrate ... do.	307.31

Product	Gold	Silver	Lead	Zinc
Recovery, percent:				
In jig concentrate	16.6	2.9	2.2	0.2
In lead concentrate	74.4	85.6	94.3	15.9
In zinc concentrate	4.9	5.9	1.2	72.4
Total	95.9	94.4	97.7	88.5
Lost in tails ... percent	4.1	5.6	2.3	11.5

Product	
Ratio of concentration:	
Jig concentrate	488
Lead concentrate	7.2
Zinc concentrate	13.9
Total	4.7
Ball consumption ... pounds per ton of ore	2.5
Liner ... do.	.036
Net water consumption ... tons per ton of ore	1.6

Mill Power

Power is received from the same source for milling as for mining. The same rate and conditions also apply. Generally about 50 percent of the power is required for milling.

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The following table gives the connected power load at the mill:

	Horsepower
Crusher	20
Conveyor	5
Elevator	7-1/2
Classifier and feeder	5
Ball mill	100
Flotation and blower	87-1/2
Pumps	27-1/2
Conditioners	15
Filters and blower	10-1/2
Tailing thickener	7-1/2
Water reclaiming	3
Water supply (Dardenelles)	3
Total	291-1/2

Milling Costs

Table 6 gives the cost of milling at the Tennessee-Schuylkill Corporation for September 1938 and for a period of 9 months in the same year, as taken from the auditor's report. Table 7 summarizes milling costs for September 1938. The 9-month costs are typical of those obtained since milling began in September 1936. The September cost is higher than average, due to the inclusion of the cost of relining the ball mill.

TABLE 6. - Cost of milling at Tennessee-Schuylkill mine, Chloride, Ariz., for September 1938 and first 9 months of 1938

Tons milled	September 1938 4,278		9 months 1938 41,611	
	Amount	Per ton	Amount	Per ton
Salaries and wages:				
Supervision	$ 490.50	$ 0.1147	$ 4,599.80	$ 0.1105
Elevating and crushing	360.00	.0841	3,467.93	.0833
Grinding and classifying	405.00	.0947	3,738.49	.0899
Flotation	450.00	.1052	4,218.87	.1014
Service men	332.49	.0777	3,079.48	.0740
Total salaries and wages	2,037.99	.4764	19,104.57	.4591
Power	1,510.26	.3530	14,096.04	.3388
Balls and miscellaneous supplies	816.87	.1909	5,752.71	.1383
Reagents	478.41	.1118	3,775.67	.0907
Repairs and replacements	1/ 2,418.17	1/ .5652	5,516.76	.1326
Yard and camp	71.07	.0166	889.22	.0214
Compensation insurance	77.79	.0182	724.23	.0174
Water expense	100.00	.0237	1,000.00	.0240
Xanthate royalites	42.78	.0100	416.11	.0100
Unemployment tax	67.71	.0158	681.57	.0164
Old age benefit tax	21.54	.0049	225.13	.0054
Miscellaneous and office expense 2/	507.86	.1185	5,525.26	.1329
Total milling	8,150.45	1.9050	57,707.27	1.3870

1/ Includes new lining for ball mill.

2/ One-half of unapportioned expense arbitrarily added.

TABLE 7. - Summary of milling costs, September 1938, Tennessee-Schuylkill Corporation
(4,278 tons milled)

	Operating labor	Super-vision	Power	Repairs		Balls and supplies	Reagents	Miscel-laneous	Total
				Labor	Supplies				
Crushing and elevating.	$ 0.084	-	$ 0.070	-	-	-	-	-	$ 0.154
Grinding and classifying..............	.095	-	.118	-	-	$ 0.191	-	-	.404
Flotation.............	.105	-	.165	-	-	-	$ 0.112	1/ $0.010	.392
General milling........	.016	$0.115	-	$0.078	$ 0.565	-	-	2/ .024	.798
Assaying, engineering, and office expense...		3/ .118	-	-	-	-	-	-	.118
Taxes and insurance....	4/ .039	-	-	-	-	-	-	-	.039
Total............	.339	.233	.353	.078	.565	.191	.112	.034	1.905

1/ Xanthate royalties.
2/ Rental of water right, Dardenelles mine.
3/ One-half of engineering, assaying, and office expense.
4/ Includes compensation insurance, unemployment tax, old age benefit tax, and medical expense.